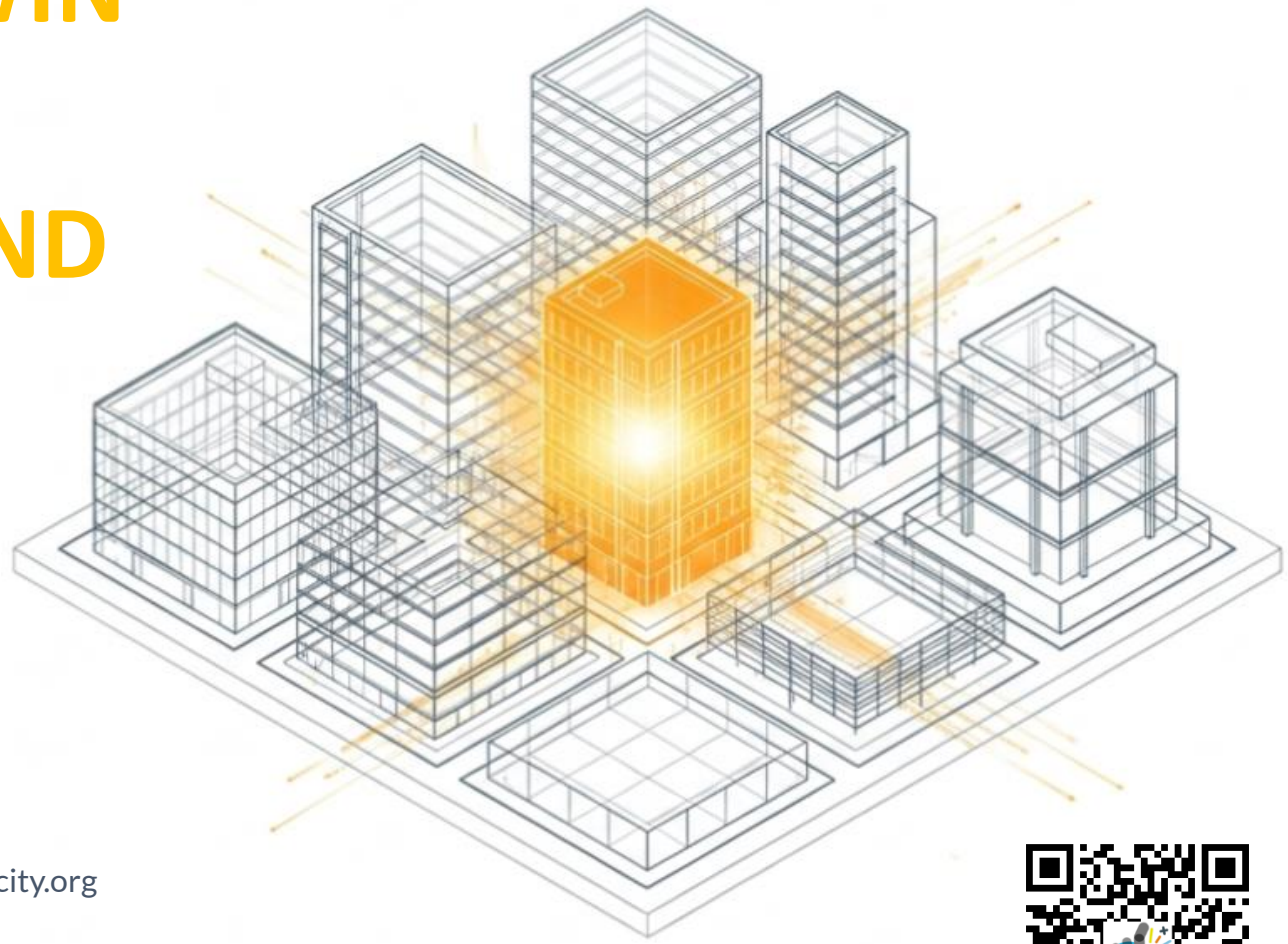
SMART CITY DIGITAL TWIN FRAMEWORK FOR SEMANTIC INDEXING AND DYNAMIC MODELLING OF 3D BUILDINGS



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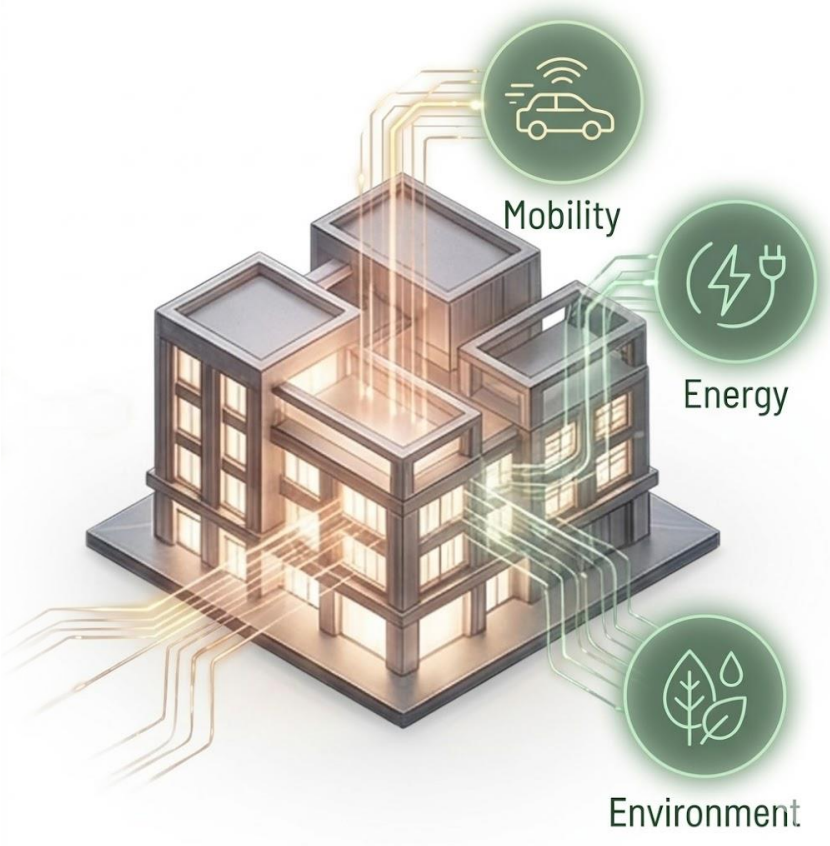
INTRODUCTION

Buildings are the fundamental units of cities

- interconnected with key urban systems
- major consumers of resources
- influence mobility patterns
- central to resilience and emergency management

Accurate building modelling is essential for informed urban planning!



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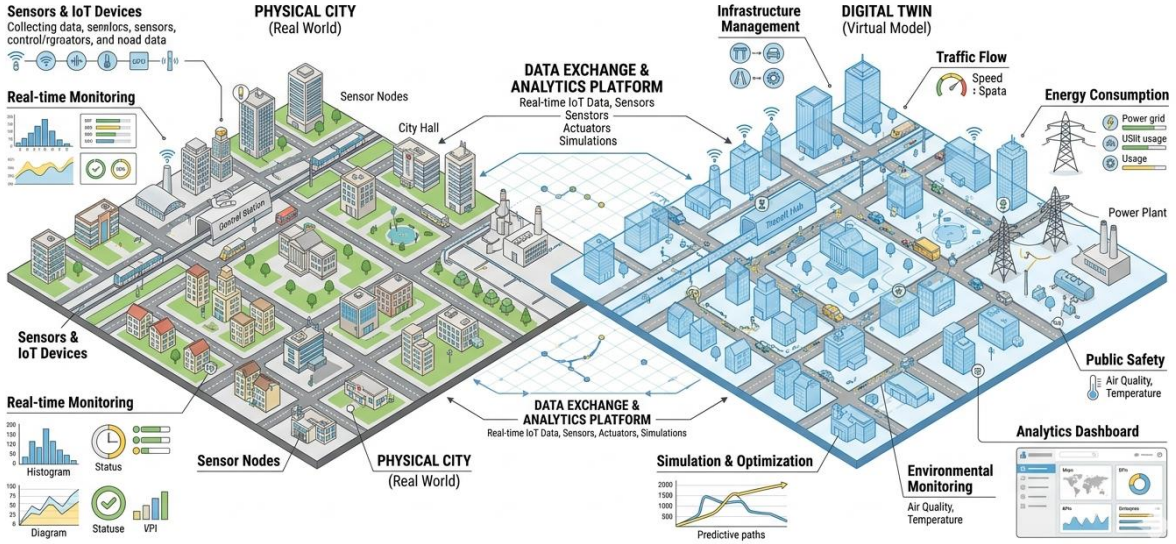
SMART CITY DIGITAL TWIN

- **Mirrors urban environment**: creating high-fidelity digital replica
- **Decision Support Systems (DSS)**: enable intelligent city management
- **Key applications:**
  - Monitoring city status
  - What-if analysis for planning
  - Optimization of critical domains



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CURRENT LIMITS AND OBJECTIVES

Static City Models

Descriptive replicas **focusing only on geometry**. These isolated graphical files allow for **visual inspection only**, offering **limited decision support** for urban planners.

Semantic & Dynamic SCDT

Operational entities linking **geometry with real-time data**. **Semantically linked** to IoT and metadata with runtime modification and **What-if scenario** analysis capabilities.

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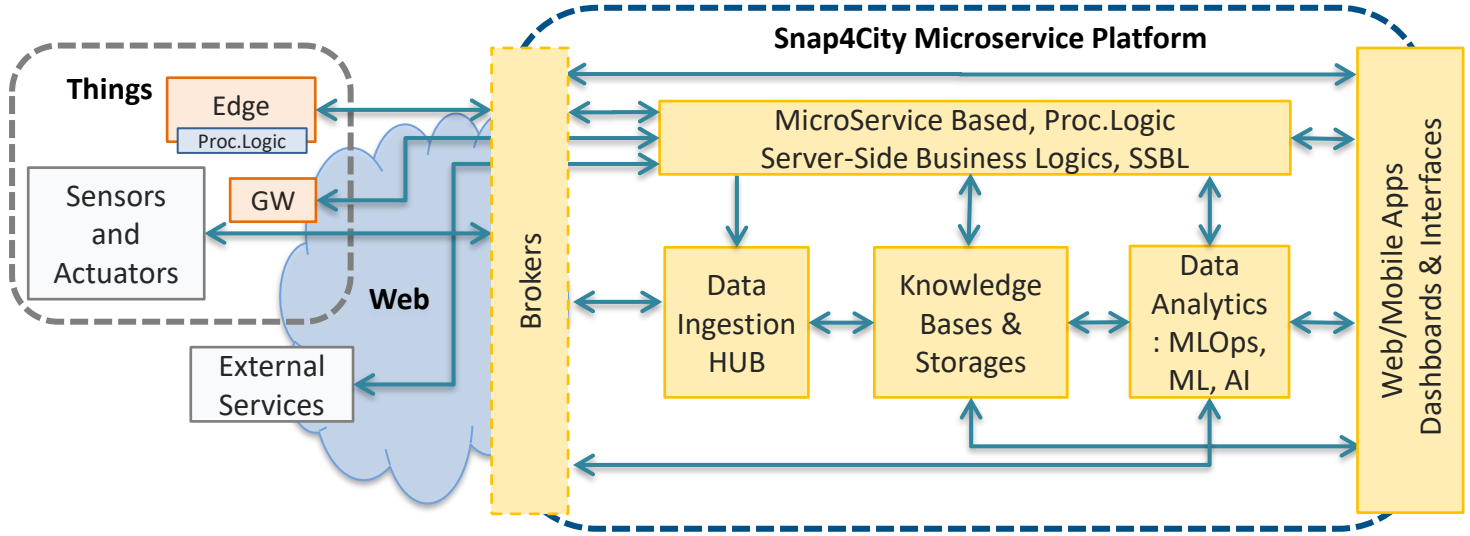
Snap4City PLATFORM

Distributed IoT Big-Data architecture to enable SCDTs

- MicroService Based Logic
- Knowledge Bases & Storages
- Data Analytics (MLOps, AI)
- Dashboards & Interfaces



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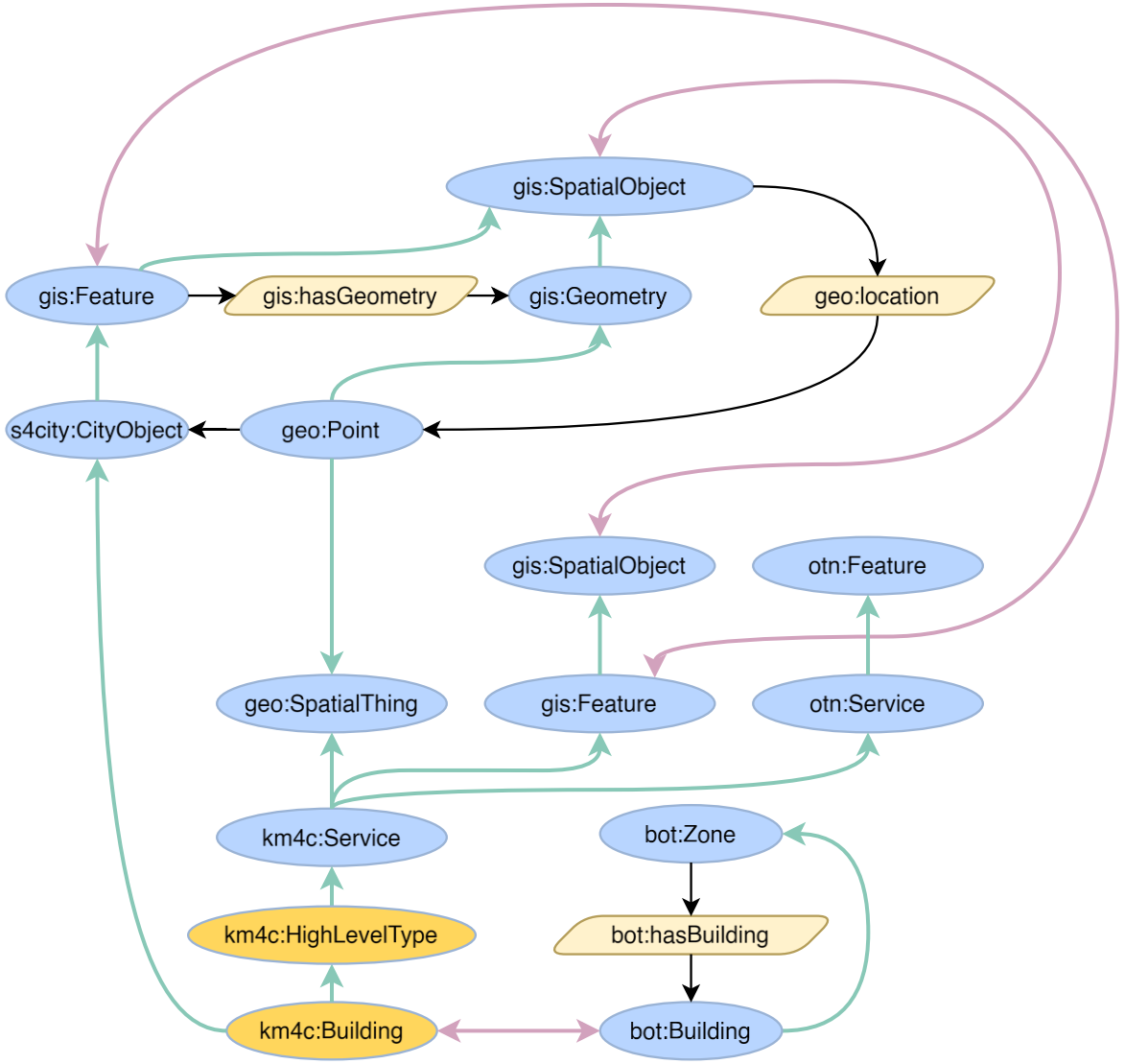
SEMANTIC MODELLING

Buildings are represented as **entities** in the KM4City ontology

The `km4c:Building` class is derived from a broader `km4c:HighLevelType`

HLT acts as a **versatile semantic label** for various urban entities

Interoperability is enforced by relating to other relevant ontologies (`s4city`, `bot`)



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BUILDING DATA MODEL

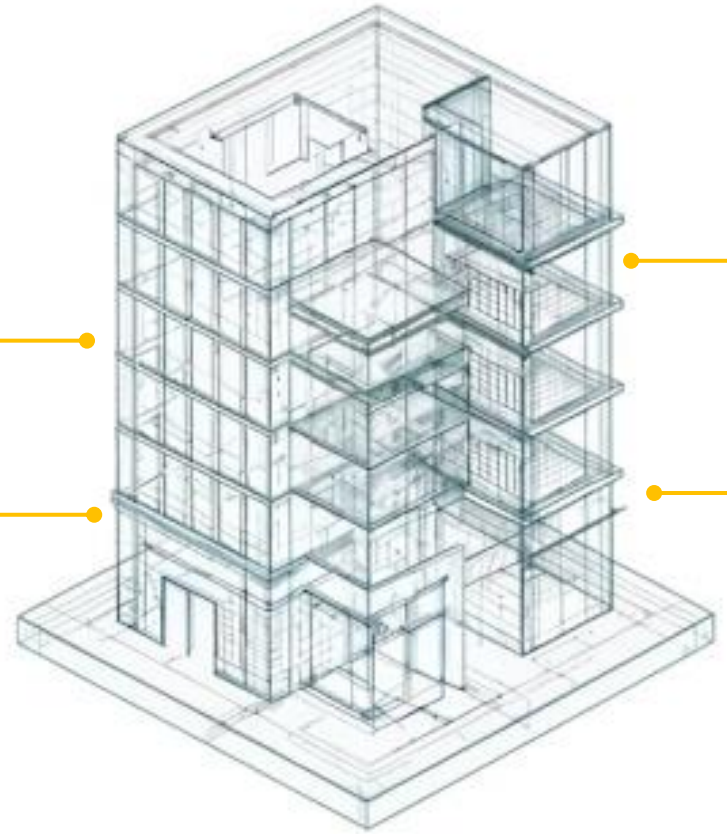
Each building is enriched with additional data following a specific data model

Location

City, Address, Postal Code

Structural

Flats, levels, capacity, height, ground shape



Classification

Name, Description, Building Type

External

OSM ID, Wikidata, Wikipedia, website

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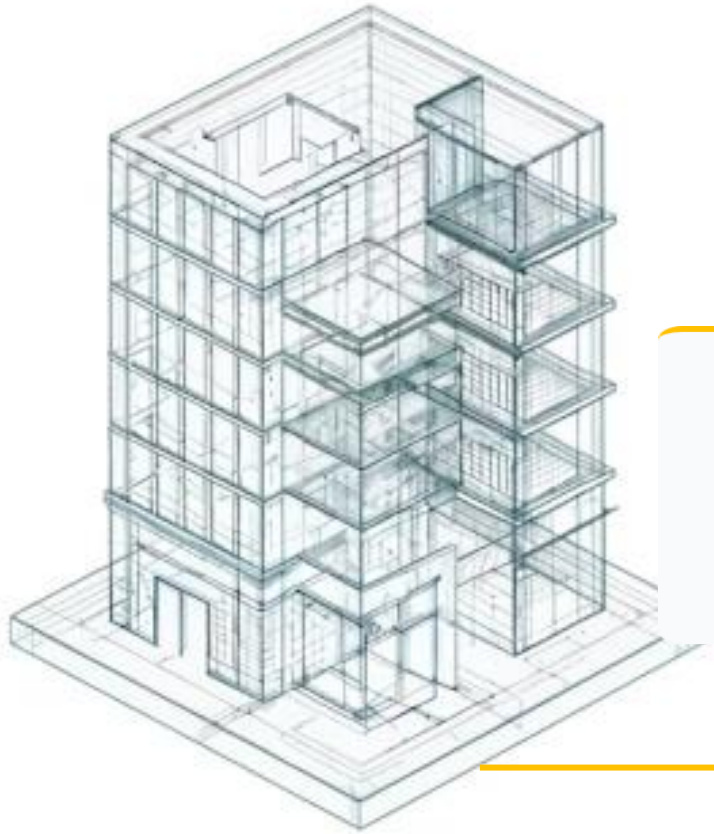
BUILDING DATA MODEL

Multiple 3D models can be associated to the same building entity



3D Model Info

File ID, type, description

3D Model Info

File ID, type, description

3D Model Info

File ID, type, description

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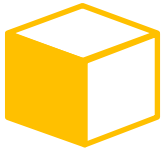
MASSIVE DATA CHALLENGES

Data Volume: Ingesting a high volume of building data requires a highly scalable and fault-tolerant processing logic

Data Reconciliation: Merging and aligning disparate data sources while robustly handling missing data



Massive 3D Rendering: Powering a visualization engine capable of rendering a massive volume of 3D models concurrently

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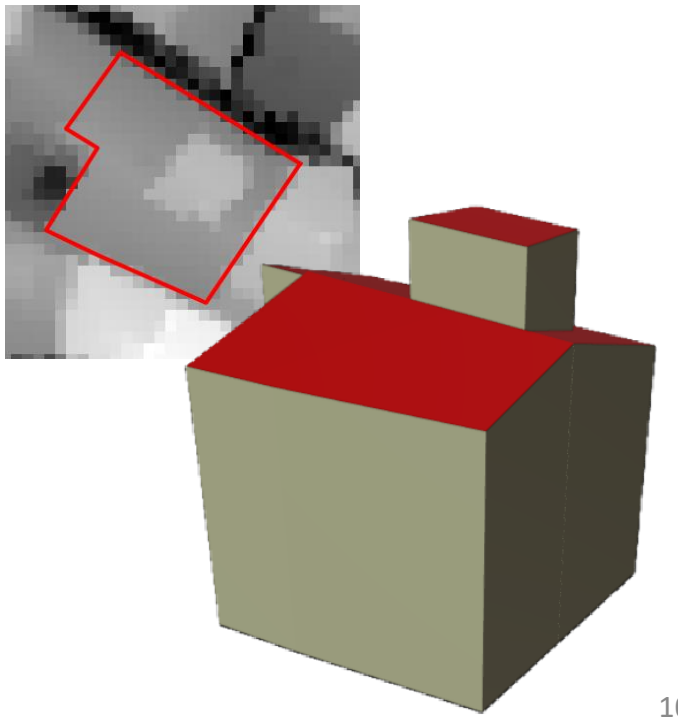
DATA SOURCES

OpenStreetMap: Provides building metadata. It is mirrored in a local Postgres database to optimize retrieval speeds

3D Building Models: Reconstructed from DTM/DSM and organized hierarchically in map tiles



Reconciliation: During construction 3D models are associated with OSM ID

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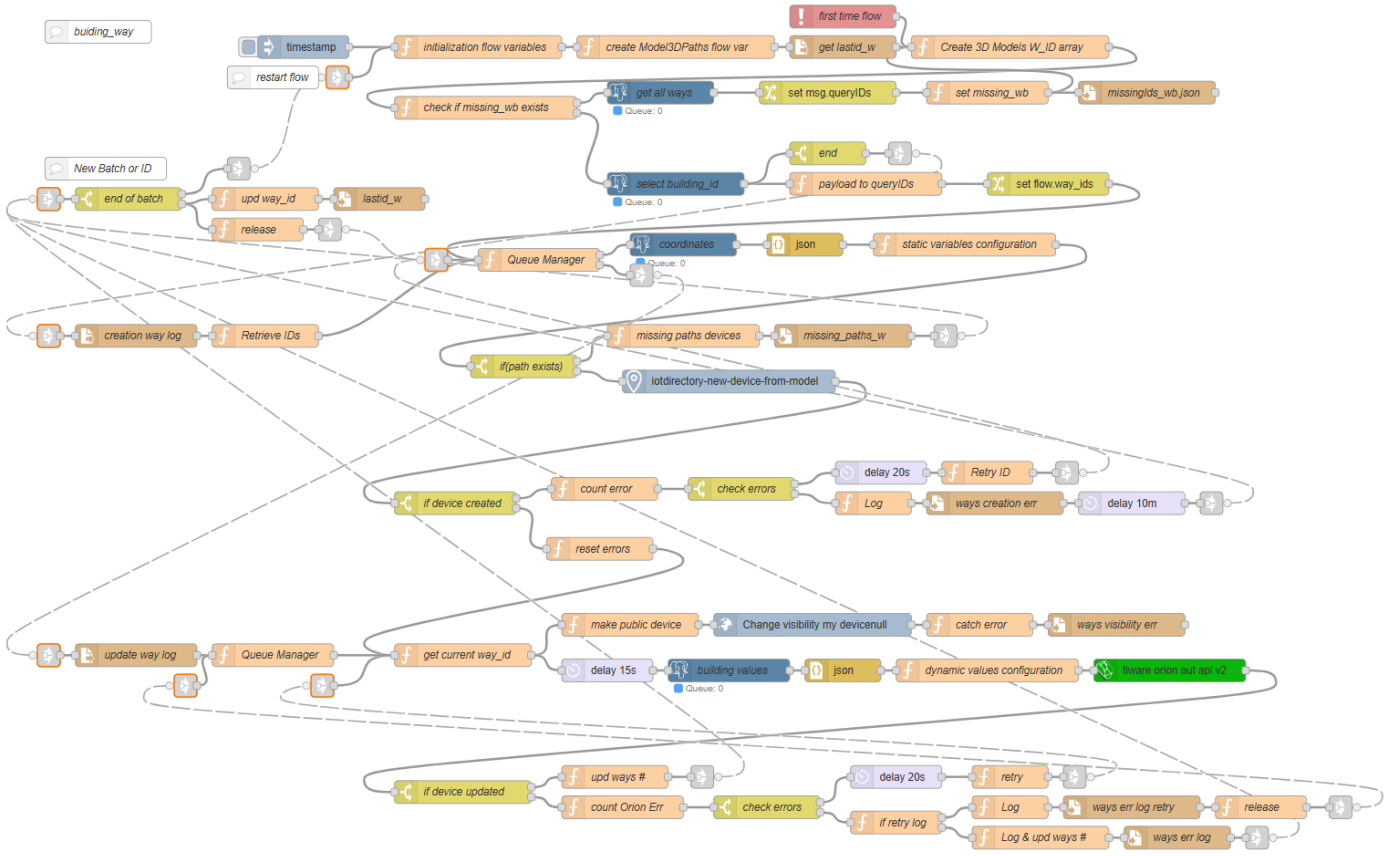
MASSIVE DATA INGESTION

Ingestion implemented as Snap4City Proc. Logic (NodeRED + Snap4City libraries)



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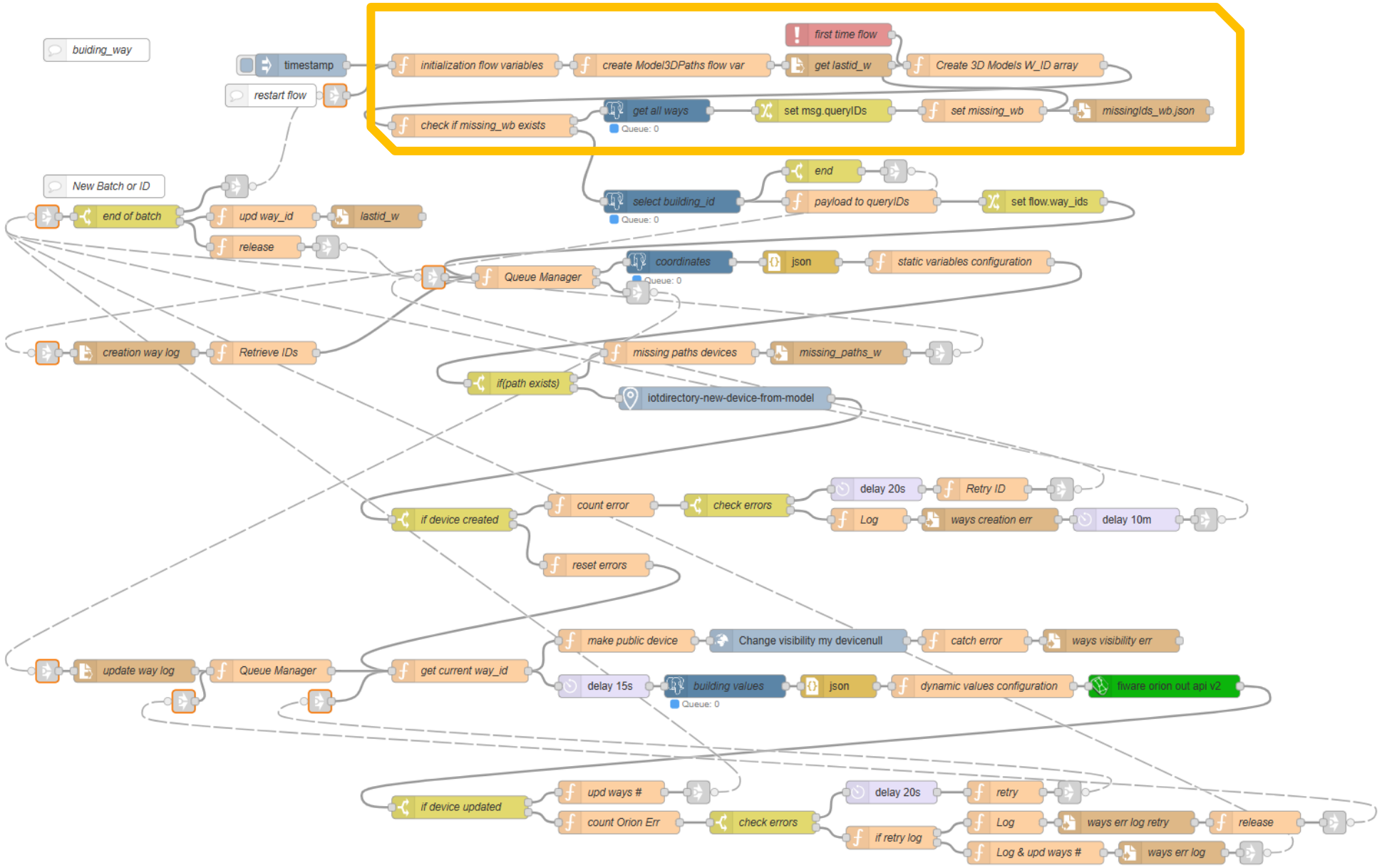
Step #0

Find 3D models without matching ID in OSM



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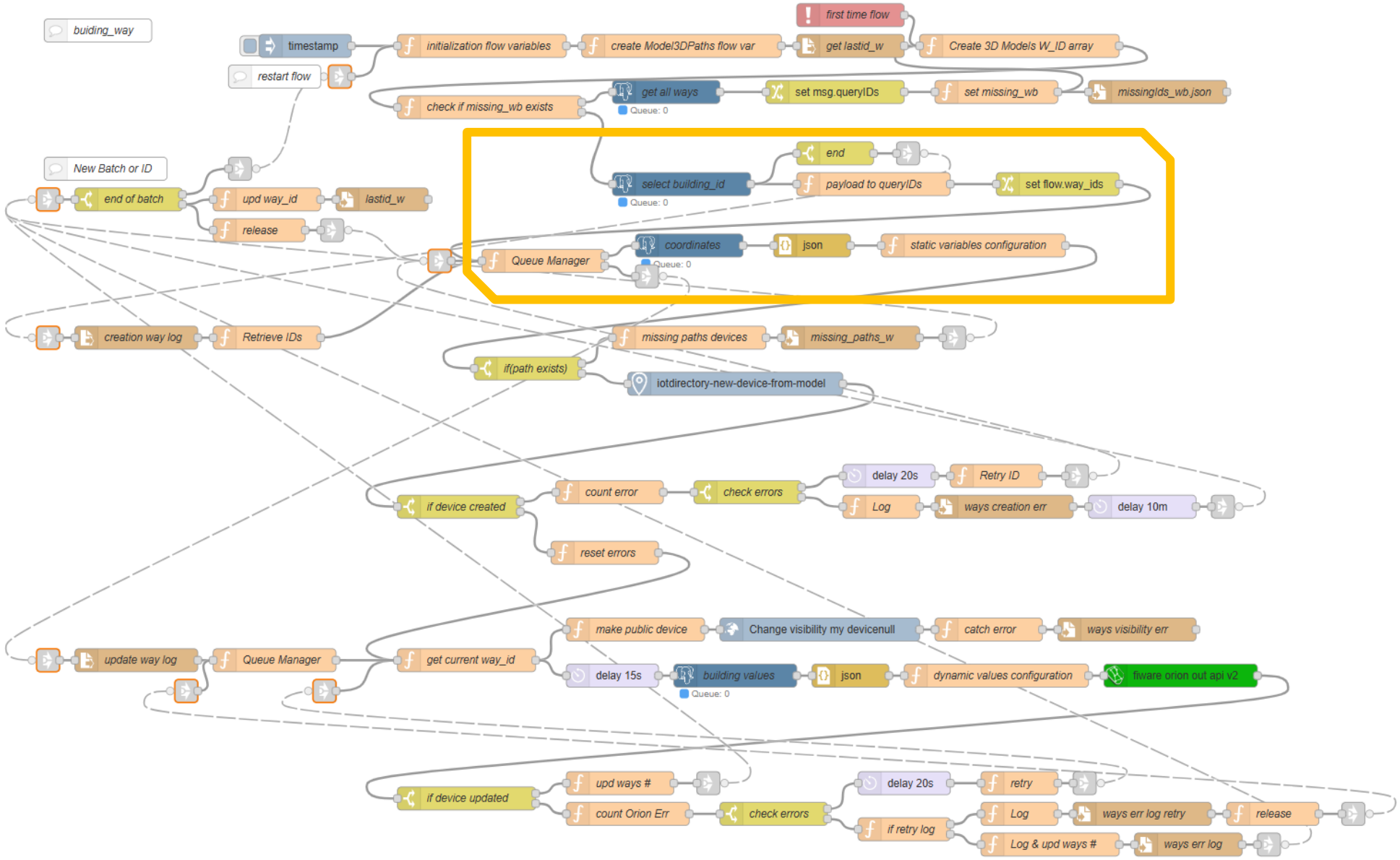
Step #0

Find 3D models without matching ID in OSM

Step #1

Batch retrieval of building info from OSM



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Step #0

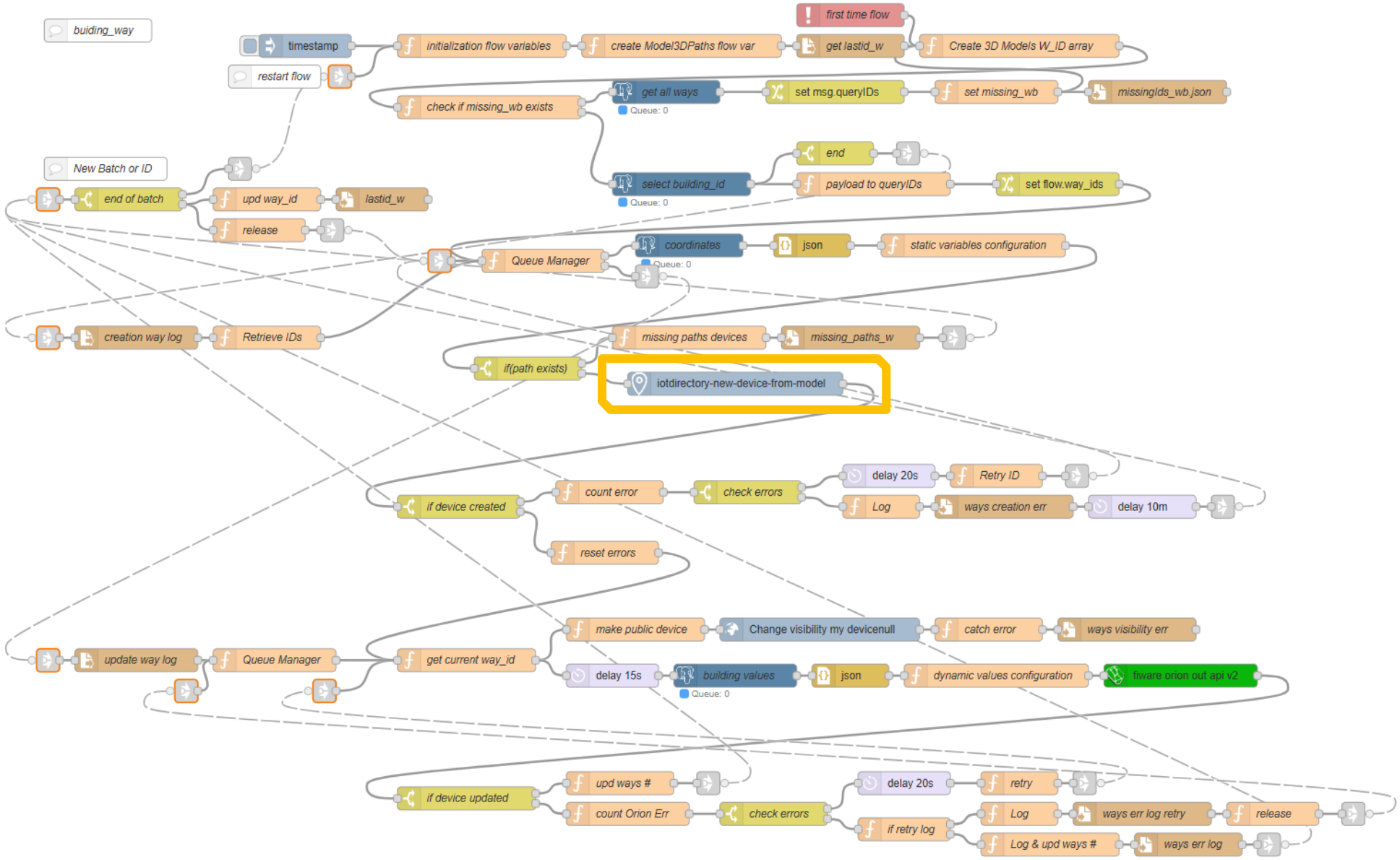
Find 3D models without matching ID in OSM

Step #1

Batch retrieval of building info from OSM

Step #2

Building entities registration



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Step #0

Find 3D models without matching ID in OSM

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Batch retrieval of building info from OSM

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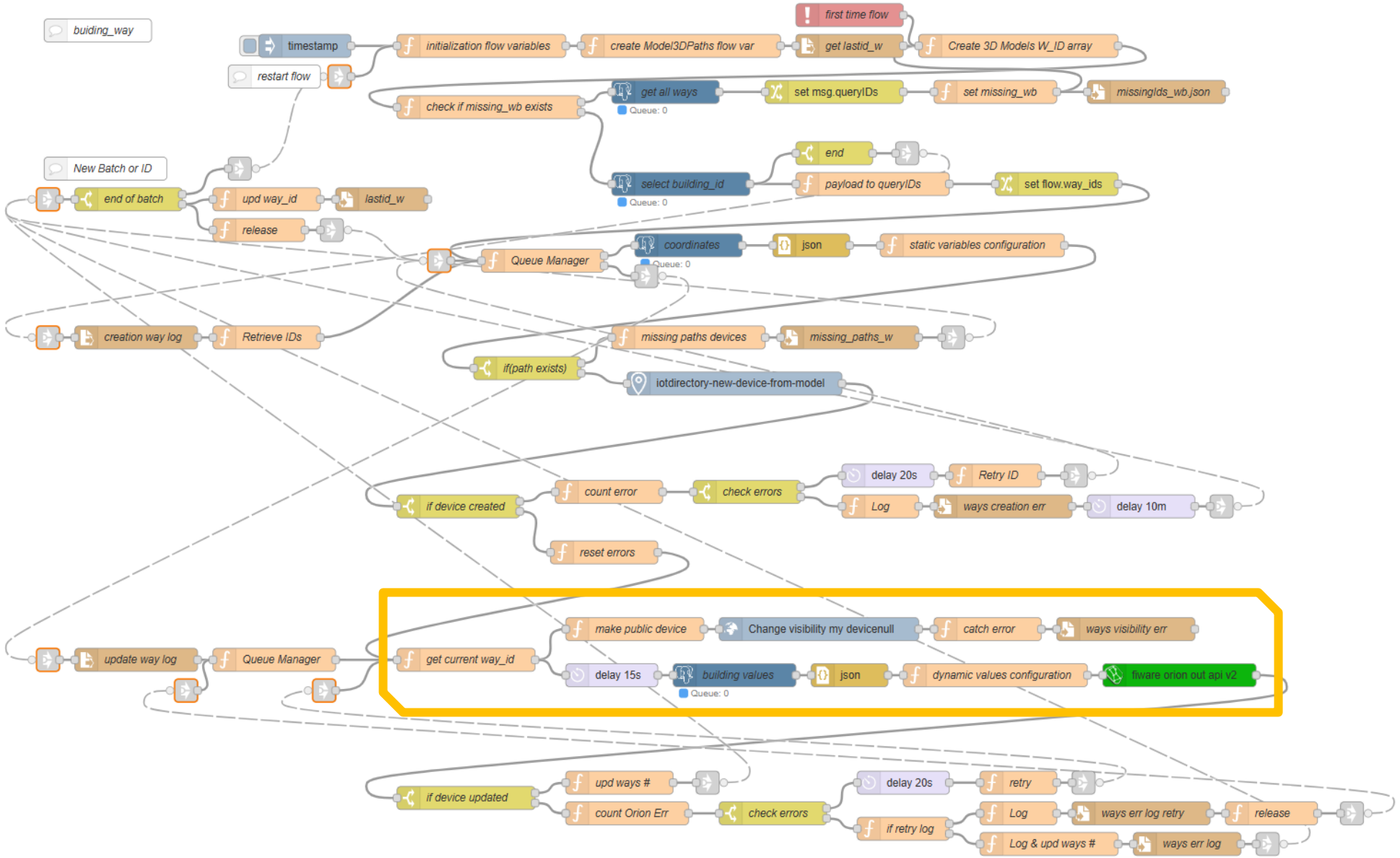
Building entities registration

Step #3

Ingestion & Permission



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Step #0

Find 3D models without matching ID in OSM

Step #1

Batch retrieval of building info from OSM

Step #2

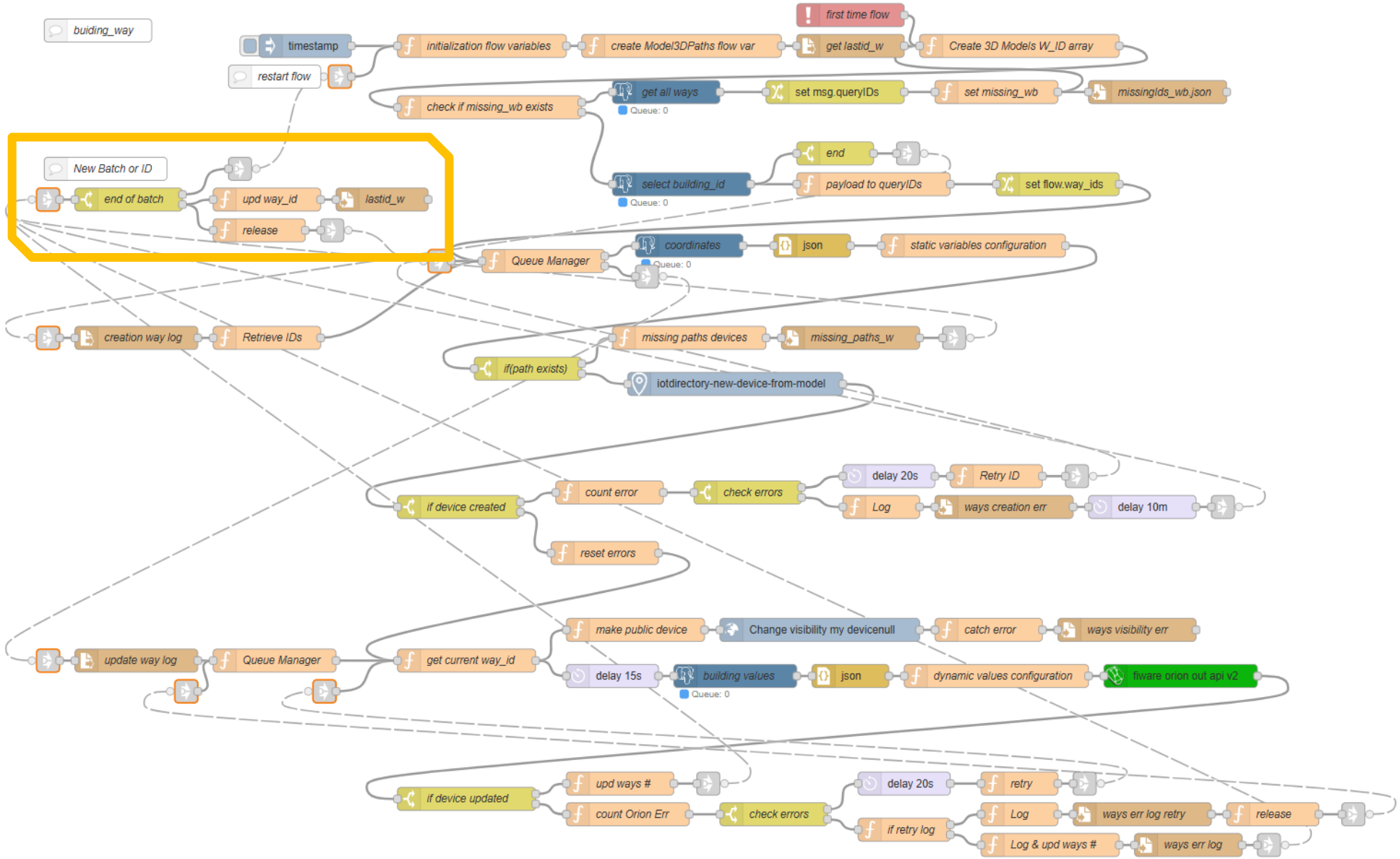
Building entities registration

Step #3

Ingestion & Permission

Step #4

Select next batch of buildings



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ERROR HANDLING FLOWS

Missing Data

Automatic detection and logging of missing 3D models.

Temporary Failures

During entity registration or data ingestion. Automatic recovery after short delay.

Persistent Failures

Logged for manual intervention while protecting the integrity of the overall ingestion pipeline.

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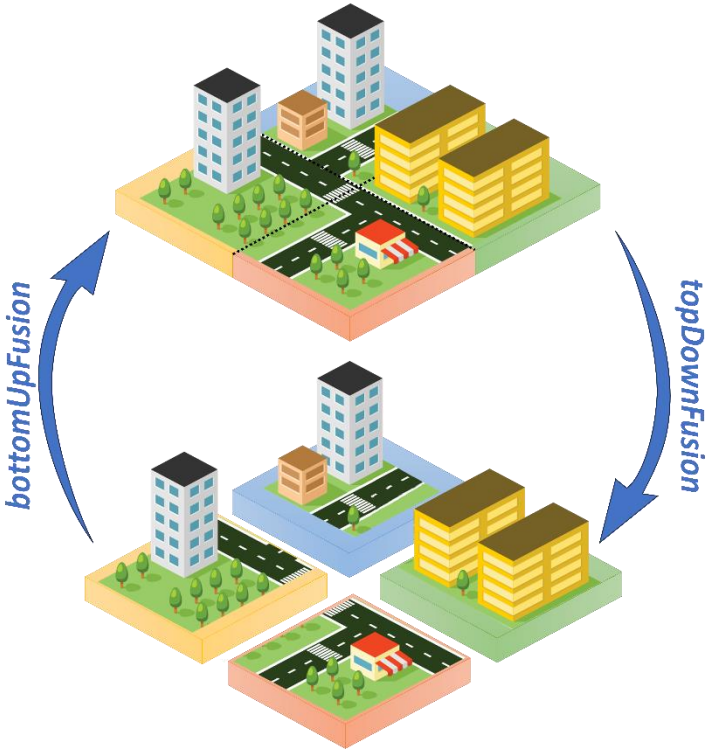
RENDERING FRAMEWORK

Based on a customized version of Deck.gl (**Snap4Deck**)

FusionLayer: Reduce server requests via smart tiling

Cache Reuse: Reuses tile data when changing zoom levels:

- *topDownFusion*: Reuses parent tile data when zooming in
- *bottomUpFusion*: Reuses child tile data when zooming out



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VALIDATION IN FLORENCE

51,029
Buildings Entities

786
Map Tiles

150 km²
Total Area Covered

Includes also full Road Network, Traffic Flows, IoT Sensors, POIs, Heatmaps, and more...

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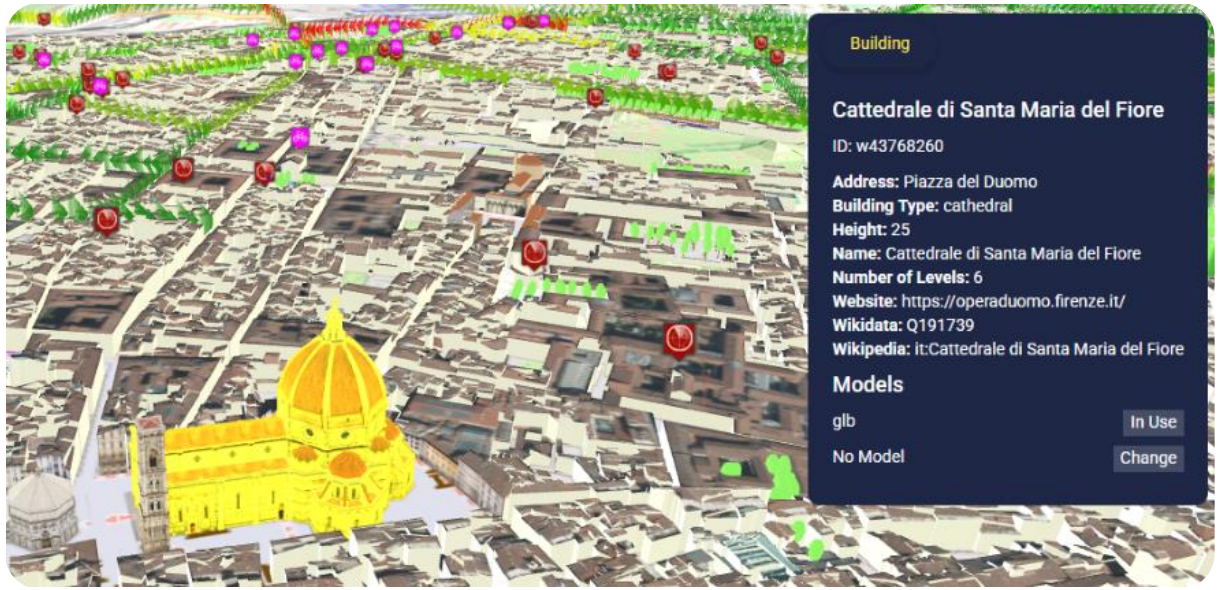
DYNAMIC & INTERACTIVE 3D VISUALIZATION

Automated Retrieval: System pulls entities and 3D visible in the viewport

Synchronization: New entities become immediately available without manual configuration

Semantic Data Retrieval: Clicking a building queries the SCDT KB for metadata and alternative 3D models



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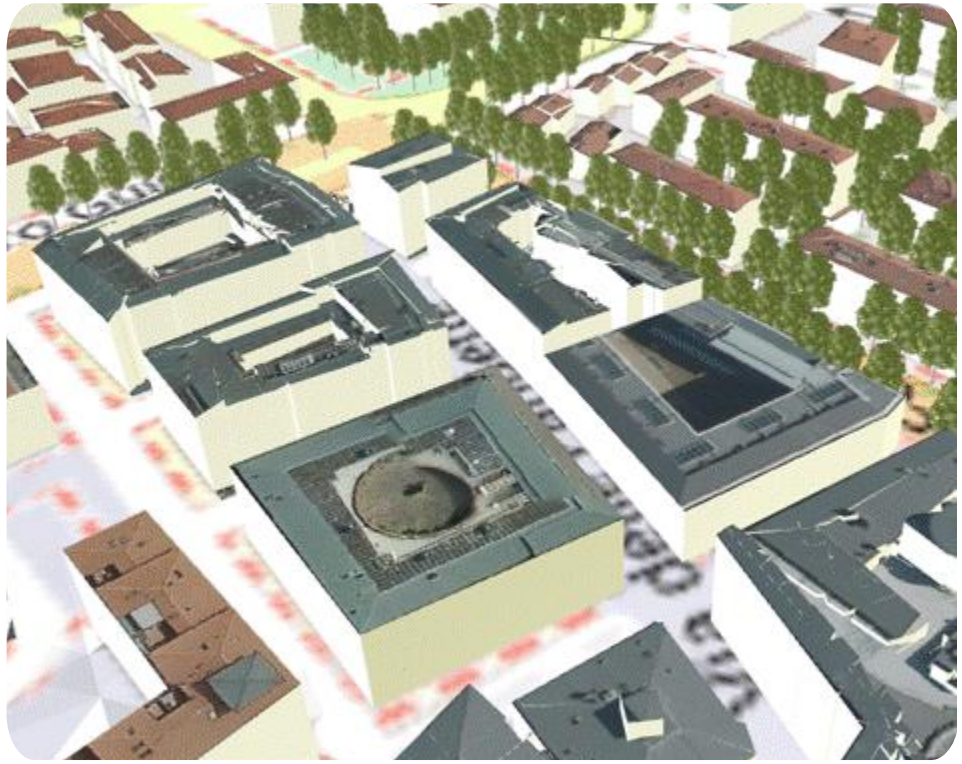
URBAN BUILDING WHAT-IF

Runtime Model Substitution: Swap default 3D model for alternatives (including BIM)

Neighbourhood Renovation: Temporarily remove existing buildings and evaluate impact of large-scale redesign



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CONCLUSION

- Snap4City SCDT links building 3D models with **rich semantic data** via KM4City ontology
- Fault-tolerant **ingestion pipeline** with automated OSM-3D reconciliation
- Massive 3D rendering on web browser via **FusionLayer**
- Supports **What-if analysis** for runtime urban planning simulation
- Validated on **Florence, Italy**: 50,000+ buildings, 150 km², plus traffic flow, IoT sensors, heatmaps, PoI, etc.

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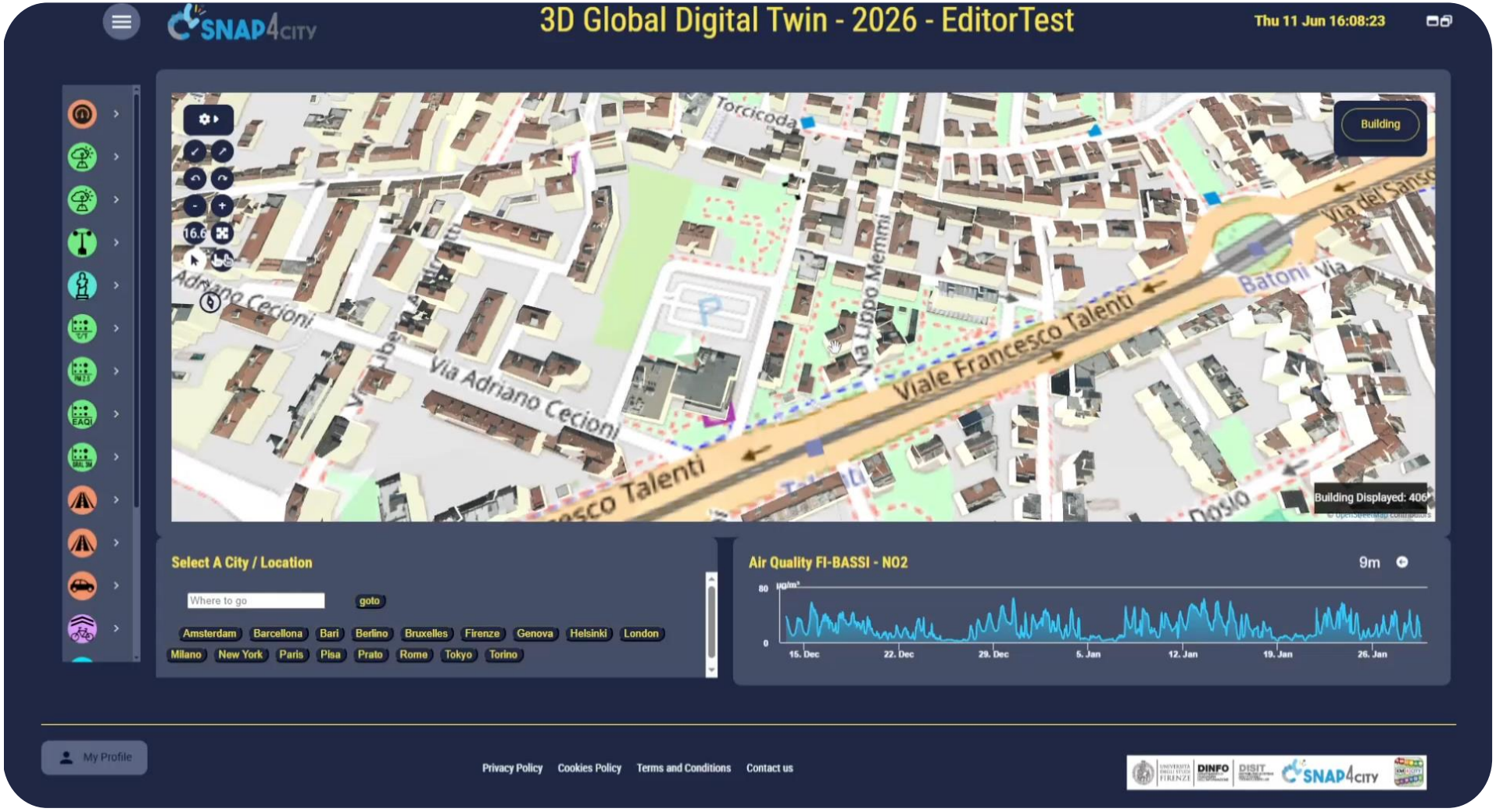
NEW FEATURE PREVIEW



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Thank you for your attention

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